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MACHINERY'S DATA SHEETS

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No. 13

Boilers and Chimneys

PRICE 25 CENTS

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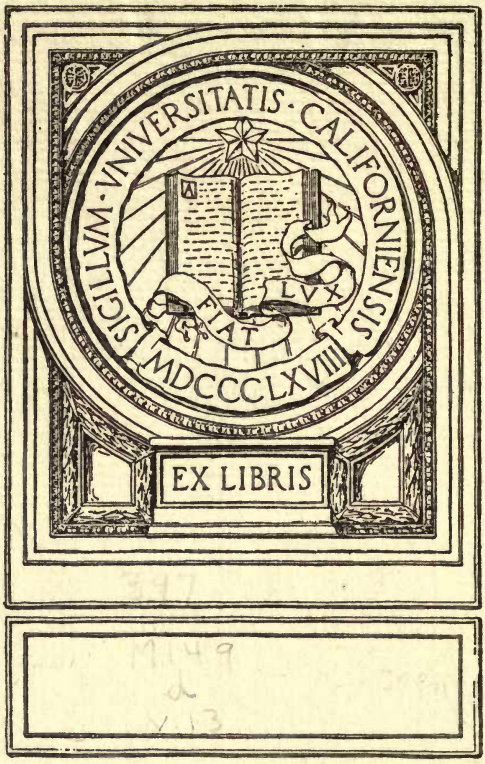
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MACHINERY'S DATA SHEET SERIES

COMPILED FROM MACHINERY'S MONTHLY DATA SHEETS AND ARRANGED WITH EXPLANATORY MATTER

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In the following pages are compiled a number of diagrams and tables relating to riveted joints, boilers, boiler setting and chimneys, carefully selected from MACHINERY'S monthly Data Sheets, issued as supplements to the Engineering and Railway Editions of MACHINERY since September, 1898. In order to enhance the value of the tables and diagrams, brief explanatory notes have been provided wherever necessary. In a note at the foot of the tables, reference is made to the page on which the explanatory note relating to the table appears.

BOILERS AND CHIMNEYS

Flue Spacing and Bracing for Boilers

On pages 4 to 7, inclusive, are given dimensions for flue spacing and bracing for boilers varying in size from 36 to 84 inches head. The dimensions given are taken from actual practice. In the table on page 4, it will be seen that the dimension C is lacking for a number of sizes. This indicates that in these sizes a number of the tubes are on the center line.

Strength of Boiler Joints

The calculation of the strength of a boiler joint is not a difficult operation. The maximum working pressure must, of course, be known, and the inner diameter of the largest course of the boiler is easily found, or is determined by the amount of steam required. From these data, the thickness of the boiler plate to be used is determined. Assume that the given pressure is 200 pounds per square inch, and the diameter 58 inches, giving a radius of 29 inches. A tensile strength of 55,000 pounds per square inch may be assumed for good steel plate. Assume 6 as a suitable factor of safety for solid plate not weakened by rivet holes. The thickness of the plate is now found by the formula:

$$t = \frac{P \times R \times F}{f_t}$$

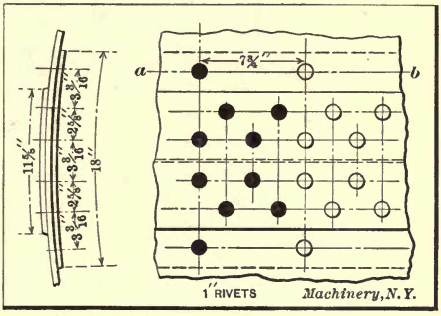
in which t = thickness of plate, in inches,
P = maximum boiler pressure, in pounds.
R = inside radius of largest course of shell,
F = factory of safety,
f_t = assumed tensile strength in pounds per square inch.

Inserting the given values, we have:

$$t = \frac{200 \times 29 \times 6}{55{,}000} = 0.633 \text{ inch},$$

or approximately a 5/8-inch plate.

Now assume that we use a riveted joint as shown in the accompanying illustration, the diameter d of the driven rivets being 1 1/16 inch and the pitch p of the outer row of the rivets 7 3/4 inches. We can now find the efficiency of the seam for tearing, that is the proportionate strength of the plate left



Riveted Joint used as Example

after allowance is made for rivet holes. This efficiency E is found by formula:

$$E = \frac{p - d}{p} = \frac{7.75 - 1.062}{7.75} = 0.863.$$

The efficiency, however, can be more easily found by using the tables given on pages 8 and 9. In the present case we find on page 9 that for driven rivets 1 1/16 inch in diameter, spaced 7 3/4 inches apart, the efficiency is 0.863.

We now proceed to find the two factors of safety, one for tearing the plate and the other for shearing the rivets.

The factor of safety for tearing, F_t =

$$\frac{E \times (f_t \times t)}{P \times R} = \frac{0.863 \times 34{,}375}{200 \times 29} = 5.12.$$

The product $f_t \times t$ may be found for varying tensile strength and plate thickness, from the table on page 10.

(Continued on page 26.)

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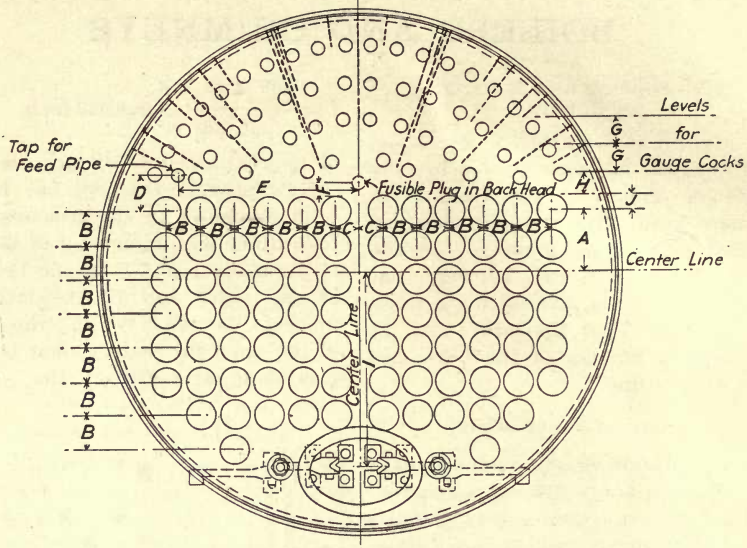
FLUE SPACING AND BRACING FOR BOILERS—I



Size of Head	No. of Tubes	Size of Tubes	A	B	C	D	E	F	G	H	I	J	Size of Manhole or Handhole below Tubes
36	32	2½	3	3½	2¼	4½	8¾	2	2½	3	13½	1¼	4×6
36	26	3	3	4		4½	8¾	2	2½	3	13	1½	4×6
36	22	3½	3	4½	2¾	4	8¾	2	3	3	13½	1¾	4×6
36	20	4	3	5	3	5	8¾	2	3	3	13½	2	4×6
42	18	4	4	5		5	15	2	3	3	12½	2	10×15
44	37	3	5½	4		4½	12	2	3½	3	15	1½	9×13
44	38	3	5¼	4		4½	12	2	3½	3	14½	1½	10×15
44	43	3	5½	4		4½	12	2	3½	3	17¾	1½	5×7
44	28	3½	5	4½	2¾	4¾	11¾	2	3½	3	15¾	1¾	9×13
44	30	3½	5	4½	2¾	4¾	11¾	2	3½	3	15	1¾	10×15
44	34	3½	5	4½	2¾	4¾	12	2	3½	3	17¾	1¾	5×7
44	23	4	5¼	5		5	10	2	3½	3	15	2	10×15
44	26	4	5¼	5		5	11	2	3½	3	17¾	2	5×7
48	44	3	5	4	2½	4½	13½	2	3	3	15½	1½	10×15
48	46	3	6½	4	2½	4½	13½	2	3	3	16½	1½	9×13
48	52	3	6½	4	2½	4½	13½	2	3	3	19½	1½	5×7
48	28	3½	4¼	4½	2¾	4¾	14	2	3	3	15	1¾	10×15
48	34	3½	6¼	4½	2¾	4¾	12½	2	3	3	16½	1¾	9×13
48	38	3½	6¼	4½	2¾	4¾	12½	2	3	3	19½	1¾	5×7
48	26	4	5	5	3	5	18	2	3	3	14½	2	10×15
48	28	4	6¼	5	3	5	18	2	3	3	16½	2	9×13
48	34	4	6¼	5	3	5	18	2	3	3	19½	2	5×7
54	56	3	7	4	2½	4½	14½	2	3	3	18	1½	10×15

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FLUE SPACING AND BRACING FOR BOILERS—II

Size of Head	No. of Tubes	Size of Tubes	A	B	C	D	E	F	G	H	I	J	Size of Manhole or Handhole below Tubes
54	60	3	6¾	4	2½	4½	16	2	3	3	19½	1½	9x13
54	64	3	6¾	4	2½	4½	16	2	3	3	22½	1½	5x7
54	44	3½	4½	4½	2¾	4¾	16	2	3½	3¼	18	1¾	10x15
54	46	3½	6½	4½	2¾	4¾	16	2	3½	3¼	19½	1¾	9x13
54	50	3½	6½	4½	2¾	4¾	16	2	3½	3¼	22½	1¾	5x7
54	34	4	6½	5	3	5	15	2	3	3	19½	2	9x13
54	36	4	6¾	5	3	5	15	2	3	3	18½	2	10x15
54	38	4	6¼	5	3	5	15	2	3	3	22½	2	5x7
60	74	3	8½	4	2½	4½	16	2	3½	3	22½	1½	10x15
60	80	3	8½	4	2½	4½	14½	2	3½	3	23	1½	10x15
60	82	3	8½	4	2½	4½	14½	2	3½	3	23	1½	10x15
60	84	3	8½	4	2½	4½	16	2	3½	3	25½	1½	5x7
60	54	3½	6	4½	2¾	4¾	19	2	3½	3	21½	1¾	10x15
60	56	3½	9	4½	2¾	4¾	14½	2	3½	3	22½	1¾	10x15
60	64	3½	9	4½	2¾	4¾	14½	2	3½	3	25½	1¾	5x7
60	44	4	4	5	3	5	18½	2	3½	3	20¾	2	10x15
60	44	4	7½	5	3	5	15	2	3½	3	22½	2	10x15
60	52	4	7½	5	3	5	15	2	3½	3	25½	2	5x7
66	88	3	5½	4	2½	4½	20¼	2	4	3	24	1½	10x15
66	96	3	9½	4	2½	4½	20¼	2	4	3	24	1½	10x15
66	98	3	9½	4	2½	4½	20¼	2	4	3	24	1½	10x15
66	66	3½	4½	4½	2¾	4½	20¾	2	4	3	24	1¾	10x15
66	74	3½	9	4½	2¾	4½	20¾	2	4	3	24	1¾	10x15
66	78	3½	9	4½	2¾	4½	20¾	2	4	3	28½	1¾	5x7
66	54	4	5½	5	3	5	21	2	4	3	24½	2	10x15
66	56	4	8	5	3	5	21	2	4	3	24½	2	10x15
66	58	4	8	5	3	5	21	2	4	3	28½	2	5x7
72	118	3	8½	4	2½	4½	22½	2	4	3	26¾	1½	10x15
72	124	3	8½	4	2½	4½	22½	2	4	3	31½	1½	5x7
72	124	3	10¾	4	2½	4½	22½	2	4	3	26¾	1½	10x15
72	86	3½	5	4½	2¾	4¾	30¾	2	4	3	27	1¾	10x15
72	92	3½	8½	4½	2¾	4¾	25	2	4	3	27	1¾	10x15
72	98	3½	8½	4½	2¾	4¾	25	2	4	3	31½	1¾	5x7
72	70	4	7	5	3	5	24¾	2	4	3	26	2	10x15
72	72	4	8¼	5	3	5	25	2	4	3	26	2	10x15
72	76	4	8¼	5	3	5	25	2	4	3	31½	2	5x7
78	100	3½	6½	4½	3	4¾	27	2	4	3	30	2	10x15
78	84	4	9	5	3½	5	26¾	2	4	3	30	2	10x15
84	92	4	7	5	3½	5	35	2	4	3	32½	2	10x15

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FLUE SPACING AND BRACING FOR BOILERS—III

Size of Head	Number of Tubes	Size of Tubes	Number of Horizontal Rows of Tubes	Number of Vertical Rows of Tubes	Number of Tubes in Top Horizontal Row (First Row)	Number of Tubes in Second Row	" " " Third "	" " " Fourth "	" " " Fifth "	" " " Sixth "	" " " Seventh "	" " " Eighth "	" " " Ninth "	Number of Tubes in First Vertical Row from Vertical Center Line	Number of Tubes in Second Vertical Row from Vertical Center Line	Number of Tubes in Third Vertical Row from Vertical Center Line	Number of Tubes in Fourth Vertical Row from Vertical Center Line	Number of Tubes in Fifth Vertical Row from Vertical Center Line	Number of Tubes in Sixth Vertical Row from Vertical Center Line	Number of Tubes in Seventh Vertical Row from Vertical Center Line	Number of Tubes in Eighth Vertical Row from Vertical Center Line	42" Braces ordinarily used above Flues	48" " " " "	54" " " " "	60" " " " "	72" " " " "
36	32	2½	5	8	8	8	8	6	2					4	4	5	3					4	2			
36	26	3	4	7	7	7	7	5						4	4	3	(4 Tubes on ℄)					4	2			
36	22	3½	4	6	6	6	6	4						4	4	3						4	2			
36	20	4	4	6	6	6	6	2						3	4	3						4	2			
42	18	4	3	7	7	7	4							2	3	3	(2 Tubes on ℄)					4	2			
44	37	3	5	9	9	9	9	8	2					4	4	5	4 (3 Tubes on ℄)					3	2			
44	38	3	5	9	9	9	9	9	2					4	4	5	4 (4 Tubes on ℄)					4	2		1	
44	43	3	5	9	9	9	9	9	7					5	5	5	4 (5 Tubes on ℄)					3	2		1	
44	28	3½	4	8	8	8	8	4						3	4	4	3					3	2		1	
44	30	3½	4	8	8	8	8	6						3	4	4	4					4	2		1	
44	34	3½	5	8	8	8	8	6	4					5	5	4	3					3	2		1	
44	23	4	4	7	7	7	7	2						3	4	3	(3 Tubes on ℄)					3				
44	26	4	4	7	7	7	7	5						4	4	3	(4 Tubes on ℄)					3				
48	44	3	5	10	10	10	10	10	4					4	4	5	5	4				5	3		2	
48	46	3	6	10	10	10	10	8	6	2				4	5	6	5	3				4	2			
48	52	3	6	10	10	10	10	8	8	6				6	6	6	5	3				4	2			
48	28	3½	4	8	8	8	8	4						3	3	4	4					5	3		1	
48	34	3½	5	8	8	8	8	8	2					4	4	5	4					4	2			
48	38	3½	5	8	8	8	8	8	6					5	5	5	4					4	2			
48	26	4	4	8	8	8	8	2						3	3	4	3					5	4			
48	28	4	4	8	8	8	8	4						3	4	4	3					4	2		1	
48	34	4	5	8	8	8	8	6	4					5	5	4	3					4	2			
54	56	3	6	10	10	10	10	10	10	6				5	5	6	6	6					5		3	1
54	60	3	6	12	12	12	12	10	10	4				5	5	6	6	5	3				4		3	1
54	64	3	6	12	12	12	12	10	10	8				6	6	6	6	5	3				4		3	1
54	44	3½	5	10	10	10	10	10	4					4	4	5	5	4					6		4	2
54	46	3½	6	10	10	10	10	8	6	2				4	5	6	5	3					5		3	1
54	50	3½	6	10	10	10	10	8	8	4				6	6	5	5	3					5		3	1
54	34	4	5	8	8	8	8	8	2					4	4	5	4						5		3	1
54	36	4	5	8	8	8	8	8	4					4	4	5	5						5		3	2
54	38	4	5	8	8	8	8	8	6					5	5	5	4						5		3	2

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FLUE SPACING AND BRACING FOR BOILERS—IV

Size of Head	Number of Tubes	Size of Tubes	Number of Horizontal Rows of Tubes	Number of Vertical Rows of Tubes	Number of Tubes in Top Horizontal Row (First Row)	Number of Tubes in Second Row	" " " Third "	" " " Fourth "	" " " Fifth "	" " " Sixth "	" " " Seventh "	" " " Eighth "	" " " Ninth "	Number of Tubes in First Vertical Row from Vertical Center Line	Number of Tubes in Second Vertical Row from Vertical Center Line	Number of Tubes in Third Vertical Row from Vertical Center Line	Number of Tubes in Fourth Vertical Row from Vertical Center Line	Number of Tubes in Fifth Vertical Row from Vertical Center Line	Number of Tubes in Sixth Vertical Row from Vertical Center Line	Number of Tubes in Seventh Vertical Row from Vertical Center Line	Number of Tubes in Eighth Vertical Row from Vertical Center Line	42" Braces ordinarily used above Flues	48" " " "	54" " " "	60" " " "	72" " " "
60	74	3	7	12	12	12	12	12	12	10	4			6	6	7	7	6	5				5		3	2
60	80	3	8	12	12	12	12	12	12	10	6	4		6	7	8	8	6	5				6		3	1
60	82	3	8	12	12	12	12	12	12	10	8	4		6	7	8	8	7	5				6		3	1
60	84	3	8	12	12	12	12	12	12	10	8	6		8	8	8	7	6	5				5		3	2
60	54	3½	6	10	10	10	10	10	10	4				5	5	6	6	5					7		5	2
60	56	3½	6	10	10	10	10	10	10	6				5	6	6	6	5					5		3	2
60	64	3½	7	10	10	10	10	10	10	8	6			7	7	7	6	5					5		3	2
60	44	4	5	10	10	10	10	10	4					4	4	5	5	4					7		5	2
60	44	4	5	10	10	10	10	8	6					4	5	5	5	3					5		3	2
60	52	4	6	10	10	10	10	8	8	6				6	6	6	5	3					5		3	2
66	88	3	7	14	14	14	14	14	14	12	6			6	6	7	7	7	6	5			9		6	2
66	96	3	8	14	14	14	14	14	14	12	10	4		7	7	8	8	7	6	5			7		4	2
66	98	3	8	14	14	14	14	14	14	12	10	6		8	8	8	7	7	6	5			7		4	2
66	66	3½	6	12	12	12	12	12	12	6				5	5	6	6	6	5				8		6	3
66	74	3½	7	12	12	12	12	12	12	10	4			6	6	7	7	6	5				7		5	2
66	78	3½	7	12	12	12	12	12	12	10	8			7	7	7	7	6	5				7		5	2
66	54	4	6	10	10	10	10	10	10	4				5	5	6	6	5					8		5	2
66	56	4	6	10	10	10	10	10	10	6				5	6	6	6	5					7		5	2
66	58	4	6	10	10	10	10	10	10	8				6	6	6	6	5					7		5	2
72	118	3	9	16	16	16	16	16	16	14	12	8	4	7	8	9	9	8	7	6	5		7	5	3	2
72	124	3	9	16	16	16	16	16	16	14	12	10	8	9	9	9	9	8	7	6	5		7	5	3	2
72	124	3	9	16	14	16	16	16	16	14	14	12	6	8	8	9	9	9	8	7	4		8		6	3
72	86	3½	7	14	14	14	14	14	12	12	6			6	6	7	7	7	6	4			10	7	6	2
72	92	3½	8	14	14	14	14	14	12	12	8	4		6	7	8	8	7	6	4			7	5	3	2
72	98	3½	8	14	14	14	14	14	12	12	10	8		8	8	8	8	7	6	4			7	5	3	2
72	70	4	6	12	12	12	12	12	12	10				6	6	6	6	6	5				9	7	4	2
72	72	4	7	12	12	12	12	12	10	10	4			6	6	7	7	6	4				7	5	3	2
72	76	4	7	12	12	12	12	12	10	10	8			7	7	7	7	6	4				7	5	3	2
78	100	3½	8	14	14	14	14	14	14	12	12	6		7	7	8	8	8	7	5			10	7	5	2
78	84	4	8	12	12	12	12	12	12	12	10	2		7	7	7	8	7	6				10	7	5	2
84	92	4	7	14	14	14	14	14	14	12	10			7	7	7	7	7	6	5			11	8	5	2

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STRENGTH OF BOILER JOINTS—I

I BOILER SEAM EFFICIENCY $E = \frac{p - d}{p}$

Pitch of Rivets p	Diameter of Rivet Holes, d										
	3/8"	7/16"	1/2"	9/16"	5/8"	11/16"	3/4"	13/16"	7/8"	15/16"	1"
1"	.625	.562	.500								
1 1/16"	647	.588	529								
1 1/8"	.667	.611	.556	.500							
1 3/16"	.684	.632	.579	.526							
1 1/4"	.700	.650	.600	.550	.500						
1 5/16"	.714	.667	.619	.585	.524						
1 3/8"	.727	.682	.636	.591	.545	.500					
1 7/16"	.739	.696	.652	.609	.565	522					
1 1/2"	750	.708	.667	.625	.583	.542	.500				
1 9/16"	.760	.720	.680	.640	600	.560	.520				
1 5/8"	.769	.731	.692	.654	.615	.577	538	.500			
1 11/16"	.778	.741	.704	.667	.630	.593	.556	.519			
1 3/4"	786	.750	714	.679	.643	.607	.571	.536	.500		
1 13/16"	.793	.759	.724	.690	.655	.621	.586	.552	.517		
1 7/8"	800	.767	.733	.700	.667	.633	.600	.567	.532	.500	
1 15/16"	806	774	.742	.710	.677	.645	.613	581	.548	.516	
2"	.812	781	.750	.719	.687	.656	.625	.594	.562	.531	.500
2 1/16"	818	788	758	727	.697	.667	.636	.606	.576	.545	.515
2 1/8"	.824	794	.765	.735	705	.676	.647	.618	.588	.559	.529
2 3/16"	.829	800	.771	.742	.714	686	.657	.629	.600	.571	.543
2 1/4"	.833	.806	.778	.750	.722	.694	.667	.639	.611	.583	.556
2 5/16"	.838	.811	.784	.757	.730	.703	.676	.649	.622	.595	.568
2 3/8"	.842	.816	789	.763	.737	.711	.684	.658	.632	.605	.579
2 7/16"	.846	.820	.795	.769	744	.718	.692	.667	.641	.615	.590
2 1/2"	.850	.825	800	.775	.750	.725	700	.675	.650	.625	.600
2 9/16"	.854	.829	.805	.781	.756	732	.707	.683	.659	.634	.610
2 5/8"	.857	.833	.810	.786	.762	.738	714	.690	.667	.643	.619
2 11/16"	.860	.837	.814	.791	.767	.744	.721	.698	.674	.651	.628
2 3/4"	.864	.841	.818	.795	.773	.750	.727	.705	.682	.659	.636
2 13/16"	.867	.844	.822	.800	.778	.756	.733	.711	.689	.667	.644
2 7/8"	.870	.848	.826	.804	.783	.761	.739	.717	.696	.674	.652
2 15/16"	.872	.851	.830	.808	.787	.766	.745	.723	.702	.681	.660

STRENGTH OF BOILER JOINTS—II

II BOILER SEAM EFFICIENCY $E = \frac{p-d}{p}$

Pitch of Rivets p	Diameter of Rivet Holes, d								Pitch of Rivets						
	11/16"	3/4"	13/16"	7/8"	15/16"	1"	1 1/16"	1 1/8"		13/16"	7/8"	15/16"	1"	1 1/16"	1 1/8"
3"	.771	.750	.729	.708	.687	.667	.646	.625	5 11/16"	.857	.846	.835	.824	.813	.802
3 1/8"	.780	.760	.740	.720	.700	.680	.660	.640	5 3/4"	.859	.848	.837	.826	.815	.804
3 1/4"	.788	.769	.750	.731	.712	.692	.673	.654	5 13/16"	.860	.849	.839	.828	.817	.806
3 5/16"	.792	.774	.755	.736	.717	.698	.679	.660	5 7/8"	.862	.851	.840	.830	.819	.809
3 3/8"	.796	.778	.759	.741	.722	.704	.685	.667	5 15/16"	.863	.853	.842	.832	.821	.811
3 7/16"	.800	.782	.764	.745	.727	.709	.691	.673	6"	.865	.854	.844	.833	.823	.813
3 1/2"	.804	.786	.768	.750	.732	.714	.696	.679	6 1/16"	.866	.856	.845	.835	.825	.814
3 9/16"	.807	.789	.772	.754	.737	.719	.702	.684	6 1/8"	.867	.857	.847	.837	.827	.816
3 5/8"	.810	.793	.776	.759	.741	.724	.707	.690	6 3/16"	.869	.859	.848	.838	.828	.818
3 11/16"	.814	.797	.780	.763	.746	.729	.712	.695	6 1/4"	.870	.860	.850	.840	.830	.820
3 3/4"	.817	.800	.783	.767	.750	.733	.717	.700	6 5/16"		.861	.851	.842	.832	.822
3 13/16"	.820	.803	.787	.770	.754	.738	.721	.705	6 3/8"		.863	.853	.843	.833	.824
3 7/8"	.823	.806	.790	.774	.758	.742	.726	.710	6 7/16"		.864	.854	.845	.835	.825
3 15/16"	.825	.810	.794	.778	.762	.746	.730	.714	6 1/2"		.865	.856	.846	.837	.827
4"	.828	.812	.797	.781	.766	.750	.734	.719	6 9/16"		.867	.857	.848	.838	.829
4 1/16"	.831	.815	.800	.785	.769	.754	.738	.723	6 5/8"		.868	.858	.849	.840	.830
4 1/8"	.833	.818	.803	.788	.773	.758	.742	.727	6 11/16"		.869	.860	.850	.841	.832
4 3/16"	.836	.821	.806	.791	.776	.761	.746	.731	6 3/4"		.870	.861	.852	.843	.833
4 1/4"	.838	.824	.809	.794	.779	.765	.750	.735	6 13/16"			.862	.853	.844	.835
4 5/16"	.841	.826	.812	.797	.783	.768	.754	.739	6 7/8"			.864	.855	.845	.836
4 3/8"	.843	.829	.814	.800	.786	.771	.757	.743	6 15/16"			.865	.856	.847	.838
4 7/16"	.845	.831	.817	.803	.789	.775	761	.746	7			.867	.857	.848	.839
4 1/2"	.847	.833	.819	.806	.792	.778	.764	.750	7 1/16"			.867	.858	.850	.841
4 9/16"	.849	.836	.822	.808	.795	.781	.767	.753	7 1/8"			.868	.860	.851	.842
4 5/8"	.851	.838	.824	.811	.797	.784	.770	.757	7 3/16"				.861	.852	.843
4 11/16"	.853	.840	.827	.813	.800	.787	.773	.760	7 1/4"				.862	.853	.845
4 3/4"	.855	.842	.829	.813	.803	.789	.776	.763	7 5/16"				.863	.855	.846
4 13/16"	.857	.844	.831	.818	.805	.792	.779	.766	7 3/8"				.864	.856	.847
4 7/8"	.859	.846	.833	.821	.808	.795	.782	.769	7 7/16"				.866	.857	.849
4 15/16"	.861	.848	.835	.823	.810	.797	.785	.772	7 1/2"				.867	.858	.850
5"	.863	.850	.838	.825	.813	.800	.788	.775	7 5/8"				.869	.861	.852
5 1/16"		.852	.840	.827	.815	.802	.790	.778	7 3/4"				.870	.863	.855
5 1/8"		.854	.841	.829	.817	.805	.793	.780	7 7/8"					.865	.857
5 3/16"		.855	.843	.831	.819	.807	.795	.783	8"					.867	.859
5 1/4"		.857	.845	.833	.821	.810	.798	.786	8 1/8"					.869	.862
5 5/16"		.859	.847	.835	.824	.812	.800	.788	8 1/4					.871	.864
5 3/8"		.860	.849	.837	.826	.814	.802	.791	8 1/2					.875	.868
5 7/16"			.851	.839	.828	.816	.805	.793	8 3/4					.879	.871
5 1/2"			.852	.841	.830	.818	.807	.795							
5 9/16"			.854	.843	.831	.820	.809	.798							
5 5/8"			.856	.844	.833	.822	.811	.800							

MACHINERY's Data Sheet No. 66. Explanatory note: Page 3.

STRENGTH OF BOILER JOINTS—III

PRODUCT OF TENSILE STRENGTH AND PLATE THICKNESS ($ft \times t$)

Plate Thickness t	Tensile Strength of Plate, Lbs. per Sq. In					
	45000	50000	55000	60000	65000	
$\frac{1}{4}$"	11250	12500	13750	15000	16250	
$\frac{5}{16}$"	14162	15625	17187	18750	20312	
$\frac{3}{8}$"	16875	18750	20625	22500	24375	
$\frac{7}{16}$"	19687	21875	24062	26250	28438	
$\frac{1}{2}$"	22500	25000	27500	30000	32500	
$\frac{9}{16}$"	25312	28125	30937	33750	36562	
$\frac{19}{32}$"	26719	29687	32656	35625	38594	
$\frac{5}{8}$"	28125	31250	34375	37500	40625	
$\frac{21}{32}$"	29531	32812	36094	39375	42656	
$\frac{11}{16}$"	30937	34375	37812	41250	44687	
$\frac{23}{32}$"	32344	35937	39531	43125	46719	
$\frac{3}{4}$"	33750	37500	41250	45000	48750	

SHEARING RESISTANCE OF RIVETS = $nf_s A$

Note:- Using for f_s, shearing strength of rivet iron = 38000 lbs. per sq. in
Diameter of driven rivet equals diameter of rivet hole

Diameter of Driven Rivet	"A" Area Sheared Sq. In.	Number of Rivets Sheared = n									
		½	1	2	3	4	5	6	7	8	9
7/16"	.15033	2856	5713	11425	17138	22850	28563	34275	39988	45700	51413
½"	.19635	3731	7461	14923	22384	29845	37306	44768	52229	59690	67152
9/16"	.24850	4721	9443	18886	28329	37772	47215	56658	66101	75544	84987
5/8"	.30680	5829	11658	23317	34975	46634	58292	69950	81609	93267	104926
11/16"	.37122	7053	14106	28213	42319	56425	70532	84638	98745	112851	126957
¾"	.44179	8394	16788	33576	50364	67152	83940	100728	117516	134304	151092
13/16"	.51849	9851	19703	39405	59108	78810	98513	118216	137918	157621	177324
7/8"	.60132	11425	22850	45700	68550	91401	114251	137101	159951	182801	205651
15/16"	.69029	13115	26231	52462	78693	104924	131155	157386	183617	209848	236079
1"	.7854	14923	29845	59690	89535	119380	149226	179071	208916	238762	268607
1 1/16"	.88664	16846	33692	67385	101077	134769	168462	202154	235846	269539	303231
1 1/8"	.99402	18886	37773	75546	113318	151091	188864	226637	264409	302182	339955
1 3/16"	1.1075	21042	42085	84170	126255	168340	210425	252510	294595	336680	378765

RIVETED JOINTS—I

Failure of Riveted Joints.

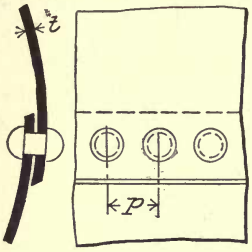
A riveted joint may fail by shearing the rivets, tearing the plate between the rivets, crushing the rivets or plate, or by a combination of two or more of the above causes.

To determine the efficiency of a riveted joint, calculate the breaking strength by the different ways in which it may fail. That method of failure giving the least result will show the actual strength of the joint. If this equals S_R, and S = tensile strength of the solid plate, then efficiency $= \frac{S_R}{S}$

Nomenclature.

d =	diameter of rivets.	P =	pitch of outer row of rivets.
t =	thickness of plate.	S =	shearing strength of rivets.
t_c =	thickness of cover plates.	T =	tensile strength of plate.
p =	pitch of inner row of rivets	C =	crushing strength of rivets.

Single-Riveted Lap-Joint.

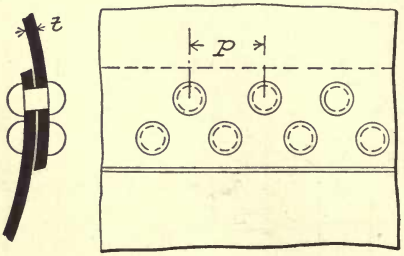


(1) Resistance to shearing one rivet $= \frac{\pi d^2}{4} S$

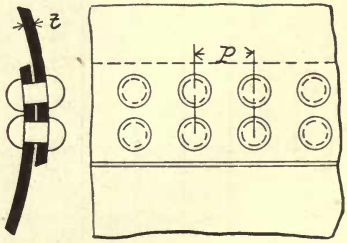
(2) " " tearing plate between rivets $= (p-d)\, t\, T$

(3) " " crushing of rivet or plate $= d\, t\, C$

Double-Riveted Lap-Joint.



Staggered Riveting



Chain Riveting.

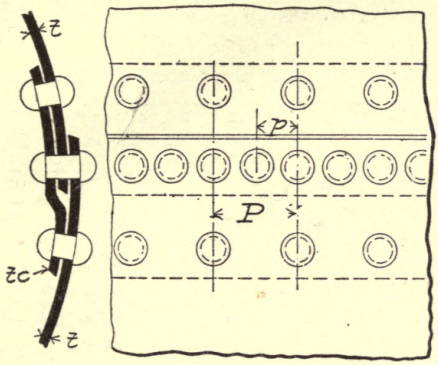
(1) Resistance to shearing two rivets $= \frac{2\pi d^2}{4} S$

(2) " " tearing between two rivets $= (p-d)\, t\, T$

(3) " " crushing in front of two rivets $= 2d\, t\, C$

RIVETED JOINTS—II

Single-Riveted Lap-Joint with Inside Cover-Plate.



(1) Resistance to tearing between outer row of rivets $= (P - d)\, t\, T$

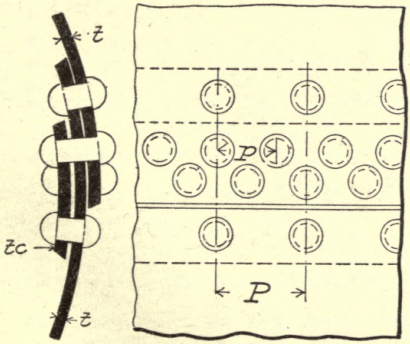
(2) Resistance to tearing between inner row of rivets, and shearing outer row of rivets $(P - 2d)\, t\, T + \frac{\pi d^2}{4} S$

(3) Resistance to shearing three rivets $\frac{3\pi d^2}{4} S$

(4) Resistance to crushing in front of three rivets $= 3\, t\, d\, C$

(5) Resistance to tearing at inner row of rivets, and crushing in front of one rivet in outer row $= (p - 2d)\, T + t\, d\, C$

Double-Riveted Lap-Joint with Inside Cover-Plate



(1) Resistance to tearing at outer row of rivets $= (P - d)\, t\, T$

(2) Resistance to shearing four rivets $= \frac{4\pi d^2}{4} S$

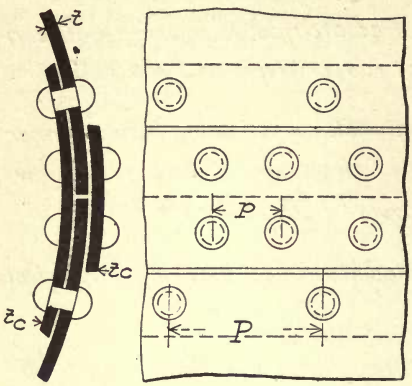
(3) Resistance to tearing at inner row and shearing outer row of rivets $(P - 1\frac{1}{2} d)\, t\, T + \frac{\pi d^2}{4} S$

(4) Resistance to crushing in front of four rivets $= 4\, t\, d\, C$

(5) Resistance to tearing at inner row of rivets, and crushing in front of one rivet $= (P - 1\frac{1}{2} d)\, t\, T + t\, d\, C$

RIVETED JOINTS—III

Double-Riveted Butt-Joint.



(1) Resistance to tearing at outer row of rivets $= (P-d)\,t\,T$

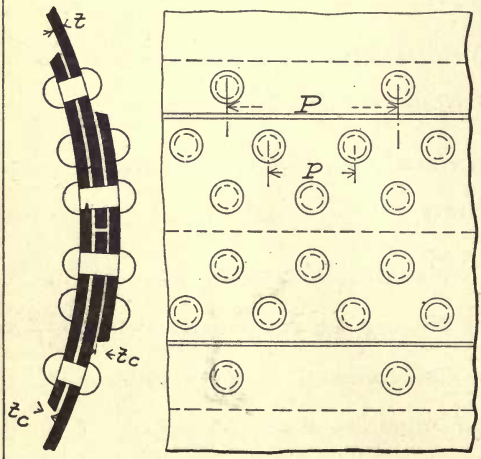
(2) Resistance to shearing two rivets in double shear and one in single shear $= \frac{5\pi d^2}{4}S$

(3) Resistance to tearing at inner row of rivets and shearing one of the outer row of rivets $= (P-2d)\,t\,T + \frac{\pi d^2}{4}S$

(4) Resistance to crushing in front of three rivets $= 3\,t\,d\,C$

(5) Crushing in front of two rivets and shearing one rivet $= 2\,t\,d\,C + \frac{\pi d^2}{4}S$

Triple-Riveted Butt-Joint.



(1) Resistance to tearing at outer row of rivets $= (P-d)\,t\,F$

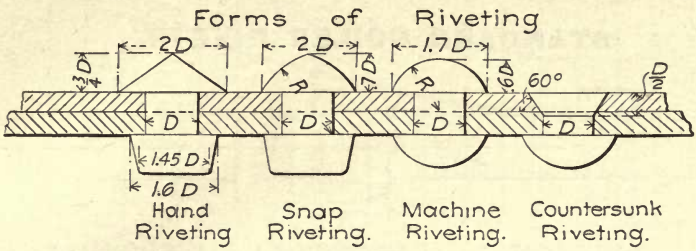
(2) Resistance to shearing four rivets in double shear and one in single shear $= \frac{9\pi d^2}{4}S$

(3) Resistance to tearing at middle row of rivets and shearing one rivet $= (P-2d)\,t\,F + \frac{\pi d^2}{4}S$

(4) Resistance to crushing in front of four rivets and shearing one rivet $= 4\,d\,t\,C + \frac{\pi d^2}{4}S$

(5) Resistance to crushing in front of five rivets $4\,d\,t\,C + d\,t_c\,C$

RIVETED JOINTS—IV



Tensile Strength of Plate per 1 inch of Width.

Thickness.	Tensile strength per square inch				
	50000	55000	60000	65000	70000
1/16	3125	3437	3750	4062	4375
1/8	6250	6875	7500	8125	8750
3/16	9375	10312	11250	12187	13125
1/4	12500	13750	15000	16250	17500
5/16	15625	17187	18750	20312	21875
3/8	18750	20625	22500	24375	26250
7/16	21875	24062	26250	28437	30625
1/2	25000	27500	30000	32500	35000
9/16	28125	30937	33750	36562	39375
5/8	31250	34375	37500	40625	43750
11/16	34375	37812	41250	44687	48125
3/4	37500	41250	45000	48750	52500
13/16	40625	44687	48750	52812	56875
7/8	43750	48125	52500	56875	61250
15/16	46875	51562	56250	60937	65625
1	50000	55000	60000	65000	70000

Shearing Strength of Rivets. (Single Shear)

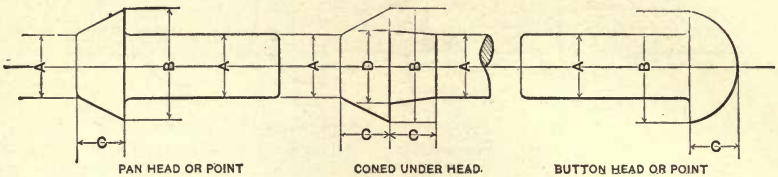
Diam. of Rivet	Area of Cross-Section.	Shearing strength per square inch.				
		30000	35000	40000	45000	50000
3/8	.1104	3312	3864	4416	4968	5520
1/2	.1963	5889	6870	7852	8833	9815
5/8	.3068	9204	10738	12272	13806	15340
3/4	.4418	13254	15463	17672	19881	22090
7/8	.6013	18039	21045	24052	27058	30065
1	.7854	23562	27489	31416	35343	39270

Crushing Strength of Rivets.

The crushing strength of rivets and plates, in joints that fail by crushing, is found by experiment to be high and irregular. In some cases it has amounted to 150,000 lbs per square inch; in a few tests it has been less than 85,000 lbs. per square inch. A value of 95,000 lbs may be used with safety for general calculations.

DIMENSIONS OF BOILER RIVETS

STANDARD BOILER RIVETS.



Industrial Press, N.Y.

A	B	C	D	Weight of 1 of Shank.	Weight of Ten Heads.	
					Pan.	Button.
1/2"	7/8"	3/8"	9/16"	.056 lbs.	.41 lbs.	.40 lbs.
9/16"	15/16"	13/32"	5/8"	.070 "	.53 "	.50 "
5/8"	1 1/16"	7/16"	11/16"	.087 "	.71 "	.68 "
11/16"	1 1/8"	15/32"	3/4"	.105 "	.87 "	.82 "
3/4"	1 1/4"	1/2"	13/16"	.126 "	1.14 "	1.06 "
13/16"	1 5/16"	17/32"	7/8"	.147 "	1.36 "	1.20 "
7/8"	1 7/16"	9/16"	15/16"	.170 "	1.71 "	1.56 "
15/16"	1 1/2"	5/8"	1"	.195 "	2.11 "	1.94 "
1"	1 5/8"	11/16"	1 1/16"	.222 "	2.71 "	2.51 "
1 1/16"	1 11/16"	3/4"	1 1/8"	.251 "	3.23 "	3.02 "
1 1/8"	1 13/16"	25/32"	1 3/16"	.282 "	3.84 "	3.57 "
1 3/16"	1 7/8"	13/16"	1 9/32"	.314 "	4.32 "	3.99 "
1 1/4"	2"	7/8"	1 11/32"	.348 "	5.26 "	4.90 "
1 5/16"	2 1/16"	29/32"	1 13/32"	.383 "	5.86 "	5.43 "
1 3/8"	2 3/16"	15/16"	1 15/32"	.421 "	6.75 "	6.24 "
1 7/16"	2 1/4"	31/32"	1 17/32"	.460 "	7.45 "	6.83 "
1 1/2"	2 3/8"	1"	1 19/32"	.501 "	8.48 "	7.78 "
1 9/16"	2 7/16"	1 1/16"	1 21/32"	.543 "	9.57 "	8.75 "
1 5/8"	2 9/16"	1 3/32"	1 23/32"	.588 "	10.90 "	10.00 "

LENGTH OF RIVETS (UNDER HEAD)

EXAMPLE: A 1″ pan head rivet is to be used to connect plates, the sum of whose thickness is 1¾″, or whose combined weight per square foot of area is 70 pounds. On the 1″ rivet diameter line measure from the pan head line to the curve marked 1¾″ or 70 pounds; the distance found—3¼″—is the length of rivet required to make a full head and fill up a hole in the plate ⅛″ larger than the rivet body.

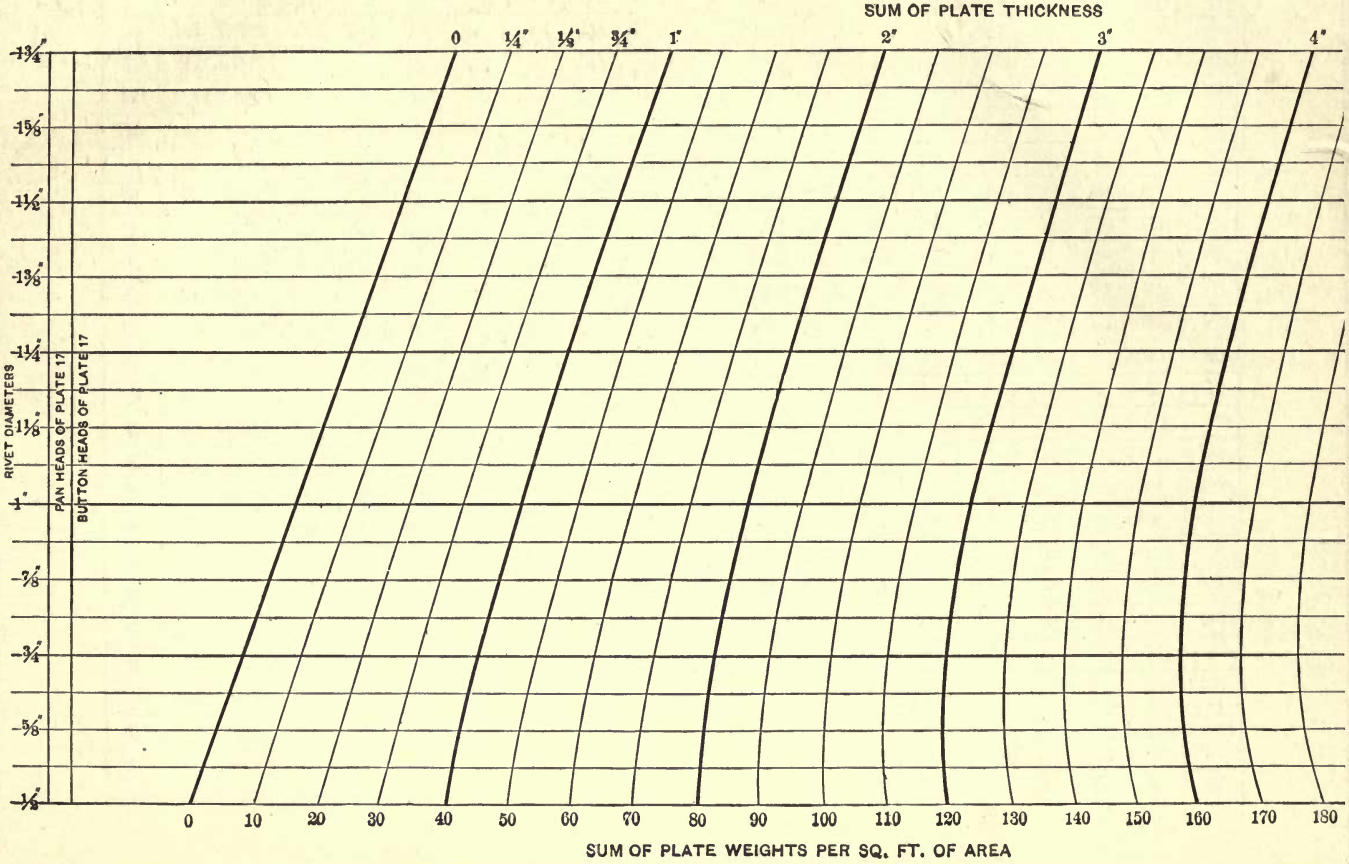


TABLE OF DIMENSIONS FOR HUNG BOILERS.

Number	H.P	Size	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1	15	36x8	36"	8'	18"	15"	13"	30"	37"	8"	20"	25¼"	12"	26"	3½"	5"	9"	49"	20"
2	20"	36x10	36"	10'	18"	15"	13"	30"	37"	12"	26"	25¼"	15"	30"	3½"	5"	9"	49"	20"
3	25	36x12	36"	12'	18"	15"	13"	30"	37"	15"	30"	25¼"	20"	36"	3½"	5"	9"	61"	20"
4	30	40x12	40"	12'	18"	15"	13"	34"	39"	15"	30"	27¼"	20"	36"	3½"	5"	9"	61"	20"
5	35	42x12	42"	12'	18"	15"	13"	36"	40"	15"	30"	28¼"	20"	36"	3½"	5"	9"	61"	24"
6	40	46x12	46"	12'	18"	15"	13"	40"	42"	15"	30"	30¼"	20"	36"	3½"	5"	9"	61"	24"
7	45	48x12	48"	12'	18"	15"	13"	42"	43"	15"	30"	31¼"	20"	36"	3½"	5"	9"	61"	24"
8	50	48x14	48"	14'	18"	15"	13"	42"	43"	20"	36"	31¼"	28"	44"	3½"	5"	9"	61"	24"
9	55	52x14	52"	14'	18"	15"	13"	46"	45"	20"	36"	33¼"	28"	44"	3½"	5"	9"	61"	24"
10	60	54x14	54"	14'	18"	15"	13"	48"	46"	20"	36"	34¼"	28"	44"	3½"	5"	9"	61"	24"
11	70	54x16	54"	16'	18"	15"	13"	48"	46"	28"	44"	34¼"	28"	44"	3½"	5"	9"	67"	24"
12	75	60x14	60"	14'	18"	15"	13"	54"	49"	20"	36"	31¼"	28"	44"	3½"	5"	9"	61"	30"
13	85	60x16	60"	16'	18"	15"	13"	54"	49"	28"	44"	31¼"	28"	44"	3½"	5"	9"	67"	30"
14	90	66x15	66"	15'	18"	15"	13"	60"	52"	24"	40"	40¼"	28"	44"	3½"	5"	9"	67"	30"
15	100	66x16	66"	16'	18"	15"	13"	60"	52"	28"	44"	40¼"	28"	44"	3½"	5"	9"	67"	30"
16	115	66x18	66"	18'	18"	15"	13"	60"	52"	28"	44"	40¼"	28"	44"	3½"	5"	9"	67"	30"
17	125	72x16	72"	16'	18"	15"	13"	66"	55"	28"	44"	43¼"	28"	44"	3½"	5"	9"	67"	30"
18	150	72x18	72"	18'	18"	15"	13"	66"	55"	28"	44"	43¼"	28"	44"	3½"	5"	9"	73"	30"
19	175	72x20	72"	20'	18"	15"	13"	66"	55"	28"	44"	43¼"	28"	44"	3½"	5"	9"	79"	30"
20	175	78x18	78"	18'	18"	15"	13"	72"	58"	28"	44"	46¼"	28"	44"	3½"	5"	9"	73"	30"
21	200	78x20	78"	20'	18"	15"	13"	72"	58"	28"	44"	46¼"	28"	44"	3½"	5"	9"	79"	30"
22	200	84x18	84"	18'	18"	15"	13"	78"	61"	28"	44"	49¼"	28"	44"	3½"	5"	9"	73"	30"
23	225	84x20	84"	20'	18"	15"	13"	78"	61"	28"	44"	49¼"	28"	44"	3½"	5"	9"	79"	30"
24	225	90x18	90"	18'	18"	15"	13"	84"	64"	28"	44"	52¼"	28"	44"	3½"	5"	9"	73"	30"
25	250	90x20	90"	20'	18"	15"	13"	84"	64"	28"	44"	52¼"	28"	44"	3½"	5"	9"	79"	30"

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TABLE OF DIMENSIONS FOR HUNG BOILERS. (Continued.)

Number	R	S	T	U	V	W	X	Y	Z	AA	BB	CC	DD	EE	FF	GG	HH	II	JJ
1	18″	20″	9″	19¼″	15½″	21″	9″	3″	5½″	89″	11′2″	73″	67″	62¾″	44¼″	43¼″	10″	4″	77″
2	18″	20″	9″	19¼″	15½″	21″	9″	3″	5½″	89″	13′2″	73″	67″	62¾″	44¼″	43¼″	10″	4″	77″
3	18″	20″	9″	19¼″	15½″	21″	9″	3″	5½″	101″	15′2″	73″	67″	62¾″	44¼″	43¼″	10″	5″	77″
4	18″	22″	9″	24″	17½″	21″	9″	3″	5½″	101″	15′2″	77″	74″	69½″	49″	48″	10″	5″	81″
5	18″	23″	9″	24″	18½″	21″	9″	3″	5½″	105″	15′2″	79″	75″	70½″	49″	48″	10″	5″	83″
6	18″	25″	9″	24″	20½″	21″	9″	3″	5½″	105″	15′2″	83′	77″	72½″	49″	48″	10″	6″	88″
7	18″	26″	9″	24″	21½″	25″	9″	3″	9½″	105″	15′2″	93″	78″	73½″	49″	48″	10″	6″	98″
8	18″	26″	9″	24″	21½″	25″	9″	3″	9½″	105″	17′2″	93″	78″	73½″	49″	48″	10″	6″	98″
9	20″	28″	9″	24″	23½″	25″	9″	3″	9½″	105″	17′4″	97″	81″	75½″	49″	48″	10″	6″	102″
10	20″	29″	9″	24″	24½″	25″	9″	3″	9½″	105″	17′4″	99″	81″	76½″	49″	48″	10″	6″	104″
11	20″	29″	9″	24″	24½″	25″	9″	3″	9½″	117″	19′4″	99″	81″	76½″	49″	48″	10″	7″	104″
12	24″	32″	12″	28″	27½″	30″	12″	3″	11½″	111″	18′3″	115″	132″	82½″	52″	51″	10″	7″	120″
13	24″	32″	12″	28″	27½″	30″	12″	3″	11½″	117″	20′3″	115″	132″	82½″	52″	51″	10″	7″	120″
14	24″	35″	12″	28″	30½″	30″	12″	3″	11½″	117″	19′3″	121″	132″	85½″	52″	51″	10″	7″	127″
15	24″	35″	12″	28″	30½″	30″	12″	3″	11½″	117″	20′3″	121″	132″	85½″	52″	51″	10″	7″	127″
16	24″	35″	12″	28″	30½″	30″	12″	3″	11½″	123″	22′3″	121″	132″	85½″	52″	51″	10″	7″	127″
17	24″	38″	12″	28″	33½″	30″	12″	3″	11½″	117″	20′3″	127″	132″	88½″	52″	51″	10″	8″	133″
18	24″	38″	12″	28″	33½″	30″	12″	3″	11½″	123″	22′3″	127″	132″	88½″	52″	51″	10″	8″	133″
19	24″	38″	16″	28″	33½″	30″	12″	3″	11½″	128″	24′3″	127″	132″	88½″	52″	51″	10″	9″	133″
20	24″	41″	16″	28″	36½″	30″	12″	3″	11½″	123″	22′7″	133″	144″	91½″	52″	51″	10″	9″	140″
21	30″	41″	16″	28″	36½″	30″	12″	3″	11½″	128″	24′7″	133″	144″	91½″	52″	51″	10″	10″	140″
22	30″	44″	16″	28″	39½″	30″	12″	3″	11½″	123″	23′1″	139″	150″	94½″	52″	51″	10″	10″	146″
23	30″	44″	16″	28″	39½″	30″	12″	3″	11½″	128″	25′5″	139″	150″	94½″	52″	51″	10″	10″	146″
24	30″	47″	16″	28″	42½″	30″	12″	3″	11½″	123″	23′1″	145″	156″	97½″	52″	51″	10″	10″	152″
25	30″	47″	16″	28″	42½″	30″	12″	3″	11½″	128″	25′5″	145″	156″	97½″	52″	51″	10″	10″	152″

TABLE OF DIMENSIONS FOR HUNG BOILERS. (Continued.)

Number	KK	LL	MM	NN	OO	PP	Fire Brick.	Com. Brick.	Wt. per Ft. of I-Beam.
1	8'0"	19"	2"	4"	6'3½"	4'1½"	600	4100	7½#
2	8'0"	19"	2"	4"	7'8½"	5'3½"	700	4200	8½#
3	8'0"	20"	2"	4"	9'0½"	6'5½"	800	4800	9¾#
4	8'6"	19"	2"	4"	9'0½"	6'5½"	850	6800	9¾#
5	8'6"	18"	2"	4"	9'0½"	6'5½"	875	7200	12¼#
6	9'6"	28"	2"	5"	9'0½"	6'5½"	900	9300	12¼#
7	9'6"	27"	2"	5"	9'0½"	6'5½"	950	10300	12¼#
8	9'6"	27"	2"	5"	9'11½"	7'3½"	1050	11400	12¼#
9	10'0"	32"	2"	5"	9'11½"	7'3½"	1300	13600	14¾#
10	10'0"	30"	2"	5"	9'11½"	7'3½"	1350	14000	14¾#
11	10'0"	32"	2"	5"	11'3½"	8'7½"	1400	14500	15#
12	11'6"	44"	2"	5"	9'11½"	7'3½"	1450	15800	15#
13	11'6"	44"	2"	5"	11'3½"	8'7½"	1550	17500	15#
14	11'6"	41"	2"	6"	10'7½"	7'11½"	1650	18000	17½#
15	11'6"	41"	2"	6"	11'3½"	8'7½"	1700	18300	17½#
16	11'6"	41"	2"	6"	13'3½"	10'7½"	1800	18500	17½#
17	11'6"	39"	2"	6"	11'3½"	8'7½"	1850	19000	17¾#
18	11'6"	39"	2"	6"	13'3½"	10'7½"	1900	20800	20¼#
19	11'6"	39"	2"	6"	15'3½"	12'7½"	1950	22000	21#
20	12'6"	49"	2"	7"	13'3½"	10'7½"	2000	22800	25#
21	12'6"	50"	2"	7"	15'3½"	12'7½"	2050	23900	25#
22	13'0"	53"	2"	7"	13'3½"	10'7½"	2100	24100	25#
23	13'0"	53"	2"	7"	15'3½"	12'7½"	2100	26000	30#
24	13'6"	56"	2"	7"	13'3½"	10'7½"	2150	27000	30#
25	13'6"	56"	2"	7"	15'3½"	12'7½"	2200	29000	35#

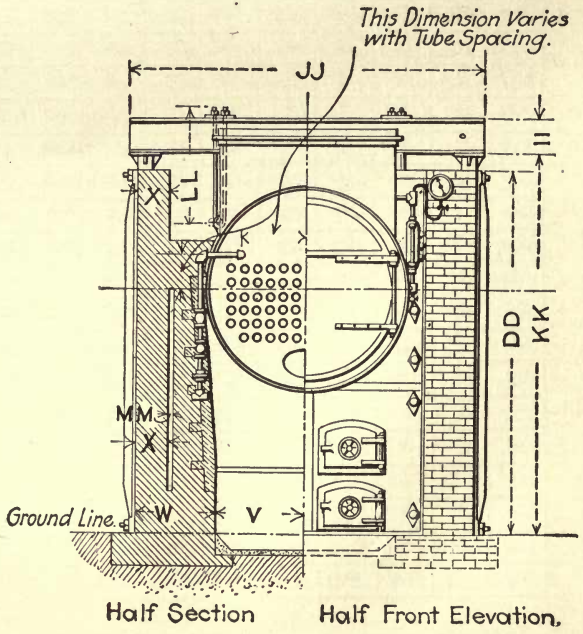
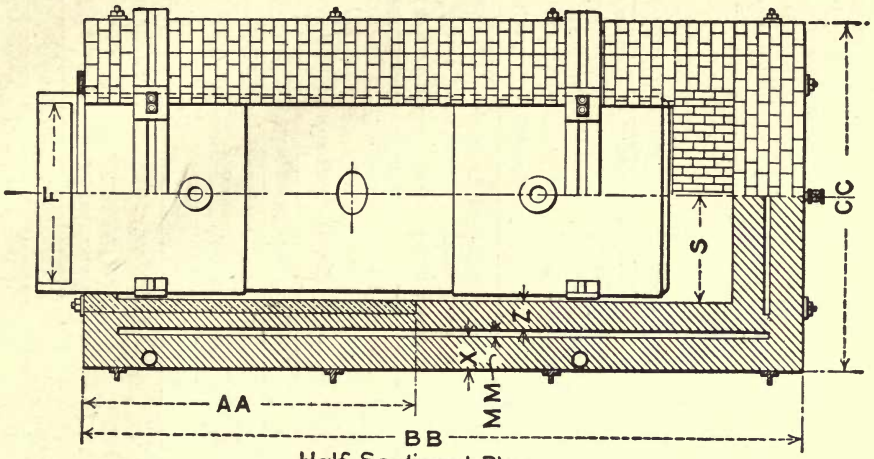
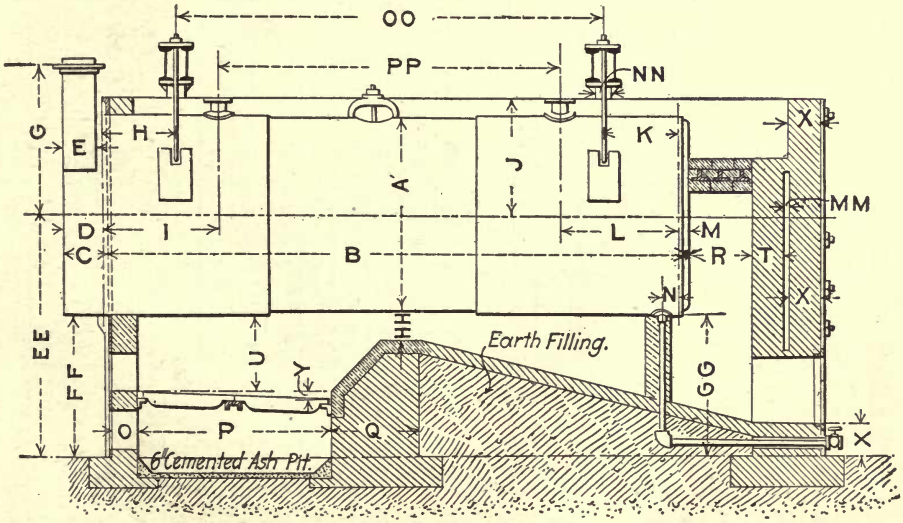


TABLE OF DIMENSIONS FOR HUNG BOILERS. (Continued.)



Half Sectional Plan.



Longitudinal Section.

DIMENSIONS FOR BOILER SETTING—I

BOILER	Horse-Power of Boiler		15	20	25	30	35	40	45	50	55	60	70	75
	Diameter of Boiler (inches)		36	36	36	40	42	46	48	48	52	54	54	60
	Length of Tubes (feet)		8	10	12	12	12	12	12	14	14	14	16	14
	Total length of Shell (feet)		9 1/2	11 1/2	13 1/2	13 1/2	13 1/2	13 1/2	13 1/2	15 1/2	15 1/2	15 1/2	17 1/2	15 1/2
	Total weight in pounds (approx)	of Boiler and Fixtures	4250	4640	5300	6400	7300	8250	8840	9650	11800	12900	15500	17100
		of Water	2800	3500	4200	5100	5800	6900	7700	9000	10200	11300	12900	13500
		of Boiler, Fixtures and Water	7050	8140	9500	11500	13100	15150	16540	18650	22000	24200	28400	30600
HANGER BOLTS	Front Head to center of Hanger (inches)		5	9	12	12	12	12	12	17	17	17	25	17
	Rear Head to center of Hanger (inches)		15 1/2	18 1/2	23 1/2	23 1/2	23 1/2	23 1/2	23 1/2	31 1/2	31 1/2	31 1/2	31 1/2	31 1/2
	Center to center of Hangers (inches)		75 1/2	92 1/2	108 1/2	108 1/2	108 1/2	108 1/2	108 1/2	119 1/2	119 1/2	119 1/2	135 1/2	119 1/2
	Diameter of Hanger Bolts (inches)		1	1	1	1	1	1	1	1	1 1/4	1 1/4	1 1/4	1 1/4
	Length of Hanger Bolts (inches) using I-Beams	one Boiler	19	19	20	19	18	28	27	27	32	30	32	44
		two Boilers	23	23	23	22	21	31	30	30	35	34	35	47
		three Boilers	25	25	25	24	23	34	33	33	38	39	40	52
	Length of Hanger Bolts (inches) using Channel Beams	one Boiler	20	21	22	21	20	30	29	29	35	33	34	46
		two Boilers	25	25	25	24	23	34	33	33	38	36	37	49
		three Boilers	27	27	27	26	25	37	36	36	41	39	40	52
COLUMNS	Center to center of Columns (inches)	one Boiler	69	69	69	73	75	78	87	87	92	94	94	110
		two Boilers	124	124	124	136	140	150	161	161	170	173	173	195
		three Boilers	180	180	180	200	206	222	234	234	247	253	253	281
	Length of Columns (feet)		8	8	8	8 1/2	8 1/2	9 1/2	9 1/2	9 1/2	10	10	10	11 1/2
	Diameter of C.I. Columns (inches)	one Boiler	4	4	4	4	4	5	5	5	5	5	5	5
		two Boilers	5	5	5	5	5	5	5	5	5	6	6	6
		three Boilers	5	5	5	5	5	5	6	6	6	6	6	6
	Thickness of Metal of C.I. Columns (inches)	one Boiler	1/2	1/2	1/2	1/2	1/2	1/2	1/2	1/2	1/2	1/2	1/2	1/2
		two Boilers	1/2	1/2	1/2	1/2	1/2	5/8	5/8	5/8	5/8	5/8	5/8	5/8
		three Boilers	5/8	5/8	5/8	3/4	3/4	3/4	5/8	5/8	5/8	5/8	5/8	3/4
	Size of Cap and Base of C.I. Columns (inches)	one Boiler	8x8	8x8	8x8	8x8	8x8	9x9	9x9	9x9	9x9	9x9	10x10	10x10
		two Boilers	10x10	10x10	10x10	10x10	10x10	10x10	10x10	10x10	10x10	12x12	12x12	12x12
		three Boilers	12x12	12x12	12x12	12x12	12x12	12x12	12x12	12x12	12x12	13x13	13x13	13x13

Contributed by G. L. Preacher, MACHINERY'S Data Sheet No. 71. Explanatory note: Page 26.

DIMENSIONS FOR BOILER SETTING—II

Horse-Power of Boiler		15	20	25	30	35	40	45	50	55	60	70	75
I-BEAMS AND CHANNELS	Center to center of Boilers (inches)	56	56	56	64	66	72	74	74	78	80	80	86
	Length of I Beams or Channel Beams required for (inches) — one Boiler	77	77	77	81	83	88	98	98	102	104	104	120
	Length of I Beams or Channel Beams required for (inches) — two Boilers	134	134	134	146	150	160	171	171	180	185	185	207
	Length of I Beams or Channel Beams required for (inches) — three Boilers	192	192	192	210	218	234	246	246	259	266	266	294
	Size of I Beams required for (inches) — one Boiler	4	4	5	5	5	6	6	6	6	6	7	7
	Size of I Beams required for (inches) — two Boilers	8	8	8	8	8	9	9	9	9	10	10	10
	Size of I Beams required for (inches) — three Boilers	10	10	10	10	10	12	12	12	12	15	15	15
	Size of Channel Beams required for (inches) — one Boiler	5	6	7	7	7	8	8	8	9	9	9	9
	Size of Channel Beams required for (inches) — two Boilers	10	10	10	10	10	12	12	12	12	12	12	12
	Size of Channel Beams required for (inches) — three Boilers	12	12	12	12	15	15	15	15	15	15	15	15
	Weight per foot of I-Beams required for (pounds) — one Boiler	7½	8½	9¾	9¾	12¼	12¼	12¼	12¼	14¾	14¾	15	15
	Weight per foot of I-Beams required for (pounds) — two Boilers	17¾	17¾	17¾	20¼	20¼	21	21	21	21	25	25	25
	Weight per foot of I-Beams required for (pounds) — three Boilers	25	25	25	30	30	31½	31½	35	35	42	42	42
	Weight per foot of Channel Beams required for (pounds) — one Boiler	6½	8	9¾	9¾	11¼	11¼	11¼	11¼	13¼	13¼	13¼	13¼
	Weight per foot of Channel Beams required for (pounds) — two Boilers	15	15	15	20	20	20½	20½	20½	20½	25	25	25
	Weight per foot of Channel Beams required for (pounds) — three Boilers	25	25	25	25	25	33	33	33	33	55	55	55
BRICK	Number of Fire Bricks required to set — one Boiler	600	700	800	850	875	900	950	1050	1300	1350	1400	1450
	Number of Fire Bricks required to set — two Boilers	1200	1400	1600	1700	1750	1800	1900	2100	2600	2700	2800	2900
	Number of Fire Bricks required to set — three Boilers	1800	2100	2400	2550	2625	2700	2850	3150	3900	4050	4200	4350
	Number of Common Bricks required to set — one Boiler	4100	4200	4800	6800	7200	9300	10300	11400	13600	14000	14500	15800
	Number of Common Bricks required to set — two Boilers	7150	7300	8400	11900	12400	15100	16700	18525	22100	22750	23600	25700
	Number of Common Bricks required to set — three Boilers	10200	10500	12000	17000	17600	20900	23100	25650	30600	31500	32700	35550

Contributed by G. L. Preacher, MACHINERY'S Data Sheet No. 71. Explanatory note: Page 26.

DIMENSIONS FOR BOILER SETTING—III

	Horse-Power of Boiler	85	90	100	115	125	150	175	175	200	200	225	225	250
BOILER	Diameter of Boiler (inches)	60	66	66	66	72	72	72	78	78	84	84	90	90
	Length of Tubes (feet)	16	15	16	18	16	18	20	18	20	18	20	18	20
	Total length of Shell (feet)	17½	16½	17½	19½	17½	19½	21½	19½	21½	19½	21½	19½	21½
	Total weight in pounds (approx) of Boiler and Fixtures, of Water, of Boiler, Fixtures and Water	19400 15400 34800	21000 15500 36500	23700 16500 40200	25100 18550 43650	28000 20800 48800	29500 23400 52900	30800 26000 56800	32000 28400 60400	34100 31600 65700	34500 33000 67500	36200 36800 73000	37000 37500 74500	39000 40000 79000
HANGER BOLTS	Front Head to center of Hanger (inches)	25	25	25	25	25	25	25	25	25	25	25	25	25
	Rear Head to center of Hanger (inches)	31½	31½	31½	31½	31½	31½	31½	31½	31½	31½	31½	31½	31½
	Center to center of Hangers (inches)	135½	127½	135½	159½	135½	159½	183½	159½	183½	159½	183½	159½	183½
	Diameter of Hanger Bolts (inches)	1¼	1¼	1¼	1¼	1¼	1¼	1½	1½	1½	1½	1½	1½	1½
	Length of Hanger Bolts (inches) one Boiler	44	41	41	41	39	39	39	49	50	53	53	56	56
	Length of Hanger Bolts (inches) two Boilers	49	46	46	46	46	46	45	58	58	61	61	64	66
	Length of Hanger Bolts (inches) three Boilers	52	49	52	52	49	51	50	64	64	67	67	70	70
	Length of Hanger Bolts (inches) using Channel Beams two Boilers	52	49	49	49	46	46							
	Length of Hanger Bolts (inches) using Channel Beams three Boilers													
	Length of Hanger Bolts (inches) using I-Beams one Boiler	46	43	43	43	41	41	42	52	52	55	55	58	58
	Length of Hanger Bolts (inches) using I-Beams two Boilers	52	49	49	49	46	46							
	Length of Hanger Bolts (inches) using I-Beams three Boilers													
COLUMNS	Center to center of Columns (inches) one Boiler	110	115	115	115	121	121	121	126	126	132	132	138	138
	Center to center of Columns (inches) two Boilers	195	207	207	207	219	219	219	230	230	242	242	254	254
	Center to center of Columns (inches) three Boilers	291	299	299	299	316	316	316	333	333	351	351	369	369
	Length of Columns (feet) one Boiler	11½	11½	11½	11½	11½	11½	11½	12½	12½	13	13	13½	13½
	Length of Columns (feet) two Boilers	5	6	6	6	6	6	6	7	7	7	7	7	7
	Length of Columns (feet) three Boilers	6	6	6	6	7	7	7	8	8	8	8	8	8
	Diameter of C.I. Coluigns (inches) one Boiler	½	⅝	⅝	⅝	⅝	⅝	⅝	⅝	⅝	¾	¾	¾	¾
	Diameter of C.I. Coluigns (inches) two Boilers	6	6	6	6	¾	¾	¾	¾	¾	¾	¾	¾	¾
	Diameter of C.I. Coluigns (inches) three Boilers	6	6	6	6	¾	¾	¾	¾	¾	¾	¾	¾	¾
	Thickness of Metal of C.I. Columns (inches) one Boiler	½	⅝	⅝	⅝	⅝	⅝	⅝	⅝	⅝	¾	¾	¾	¾
	Thickness of Metal of C.I. Columns (inches) two Boilers	⅝	¾	¾	¾	¾	¾	¾	¾	¾	¾	¾	¾	¾
	Thickness of Metal of C.I. Columns (inches) three Boilers	¾	⅞	⅞	⅞	⅞	⅞	⅞	⅞	⅞	1	1	1	1
	Size of Cap and Base of C.I. Columns (inches) one Boiler	10x10	10x10	10x10	10x10	10x10	10x10	12x12	12x12	12x12	12x12	12x12	12x12	12x12
	Size of Cap and Base of C.I. Columns (inches) two Boilers	12x12	12x12	12x12	12x12	13x13	13x13	13x13	14x14	14x14	14x14	14x14	14x14	15x15
	Size of Cap and Base of C.I. Columns (inches) three Boilers	13x13	13x13	14x14	14x14	14x14	15x15	15x15	16x16	16x16	16x16	16x16	16x16	16x16

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DIMENSIONS FOR BOILER SETTING—IV

	Horse-Power of Boiler	85	90	100	115	125	150	175	175	200	200	225	225	250
I-BEAMS AND CHANNELS	Center to center of Boilers (inches)	86	92	92	92	98	98	98	104	104	110	110	116	116
	Length of I-Beams or Channel Beams required for (inches) — one Boiler	120	127	127	127	133	133	133	140	140	146	146	152	152
	Length of I-Beams or Channel Beams required for (inches) — two Boilers	207	219	219	219	232	232	232	244	244	256	256	268	268
	Length of I-Beams or Channel Beams required for (inches) — three Boilers	294	312	313	313	330	331	331	349	349	367	367	385	385
	Size of I-Beams required for (inches) — one Boiler	7	7	7	7	8	8	9	9	10	10	10	10	10
	Size of I-Beams required for (inches) — two Boilers	12	12	12	12	15	15	15	18	18	18	18	18	20
	Size of I-Beams required for (inches) — three Boilers	15	15	18	18	18	20	20	24	24	24	24	24	24
	Size of Channel Beams required for (inches) — one Boiler	9	9	9	9	10	10	12	12	12	12	12	12	12
	Size of Channel Beams required for (inches) — two Boilers	15	15	15	15	15	15							
	Size of Channel Beams required for (inches) — three Boilers													
	Weight per foot of I-Beams required for (pounds) — one Boiler	15	17½	17½	17½	17¾	20¼	21	25	25	25	30	30	30
	Weight per foot of I-Beams required for (pounds) — two Boilers	31½	31½	35	40	42	42	45	55	55	55	60	60	65
	Weight per foot of I-Beams required for (pounds) — three Boilers	45	45	55	55	60	65	65	80	80	80	85	85	90
	Weight per foot of Channel Beams required for (pounds) — one Boiler	13¼	15	15	15	15	20	20½	20½	25	25	30	30	30
	Weight per foot of Channel Beams required for (pounds) — two Boilers	33	33	33	40	55	55							
	Weight per foot of Channel Beams required for (pounds) — three Boilers													
BRICK	Number of Fire Bricks required to set — one Boiler	1550	1650	1700	1800	1850	1900	1950	2000	2050	2100	2100	2150	2200
	Number of Fire Bricks required to set — two Boilers	3100	3300	3400	3600	3700	3800	3900	4000	4100	4200	4200	4300	4400
	Number of Fire Bricks required to set — three Boilers	4650	4950	5100	5400	5550	5700	5850	6000	6150	6300	6300	6450	6600
	Number of Common Bricks required to set — one Boiler	17500	18000	18300	18500	19000	20800	22000	22800	23900	24100	26000	27000	29000
	Number of Common Bricks required to set — two Boilers	28500	29250	29800	30100	30800	33800	35750	37050	38900	39150	42250	43900	47100
	Number of Common Bricks required to set — three Boilers	39500	40500	41300	41700	42600	46800	49500	51300	53900	54200	58500	60800	65250

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The factor of safety for shearing the rivets, $F_s =$

$$\frac{n \times A \times f_s}{P \times R \times p} = \frac{303{,}231}{200 \times 29 \times 7.75} = 6.74,$$

in which

n = total number of rivets in shear,

A = area of rivet holes,

f_s = assumed shearing strength in pounds per square inch.

The total number of rivets in shear are nine, and from the table on page 11 we find that the shearing resistance for nine 1 1/16-inch driven rivets is 303,231 pounds.

As 5 is an ample factor of safety, this boiler joint would be deemed safe.

The procedure as outlined is a very satisfactory one for determining the dimensions of a proposed joint, but the joint thus determined should be tested for strength for shearing at the outer row of rivets, and tearing at the middle row, for example, as at these places a lower factor of safety may result than for tearing at the outer row. [MACHINERY, February, 1907, Strength of Boiler Joints.]

On pages 12, 13 and 14 are given formulas for the design of riveted joints of different types. On page 15 a table is given of tensile strength of boiler plate of one inch width for varying tensile strength and thickness. A table of the strength of rivets in single shear is also given. On page 16 are given dimensions of three different types of standard boiler rivets.

On page 17 is given a diagram by means of which the length of rivet (under head) required for connecting plates of varying thicknesses may be determined. Directions for its use are given above the diagram. [MACHINERY, April, 1906, Design of a Riveted Joint; June, 1907, Strength of Boiler Joints; MACHINERY'S Reference Series No. 22; Calculations of Elements of Machine Design, Chapter IV.]

Dimensions for Boiler Setting

Pages 18 to 25 give dimensions for boiler setting. On pages 18 to 21 are given dimensions for one boiler, and on pages 22 to 25 the data necessary for several boilers, so that the two sets of tables combined give all the necessary data for any number of boilers.

In ordinary practice not more than three boilers are ever suspended from a single span of beams. In cases of four boilers, extra columns are usually placed between the two middle boilers, making thus two separate spans of two boilers each. In cases of five boilers, columns are generally placed between the second and third boilers, making two spans of two and three boilers, respectively, or additional columns are placed between the fourth and fifth boilers, making three spans of two, two, and one boiler, respectively. In some instances columns are placed between all the boilers, thus putting only one boiler to a span of beams.

Attention should be called to the values under the headings "Total Weight of Boilers and Fixtures" and "Total Weight of Water." These values, although based on experience, are, of course, only arbitrary, and must necessarily vary with the conditions. For instance, a 150 horsepower low-pressure boiler would weigh less than a similar one for high pressure. The weight of the water in the boilers would depend partly upon the number and size of tubes and braces occupying the water space. In giving sizes for beams, columns and hanger bolts, the weights of the boilers have been so assumed that the dimensions would cover all conditions.

Dimensions of Chimneys

On page 27 is given a table of heights and diameters of chimneys for different kinds of boilers. This table is based upon the grate area of the boiler, assuming the burning of from 20 to 25 pounds of coal per square foot of grate per hour. The size of the grate in many instances will vary very little with the length of the boiler. In many works the same grate is put into a Lancashire boil-

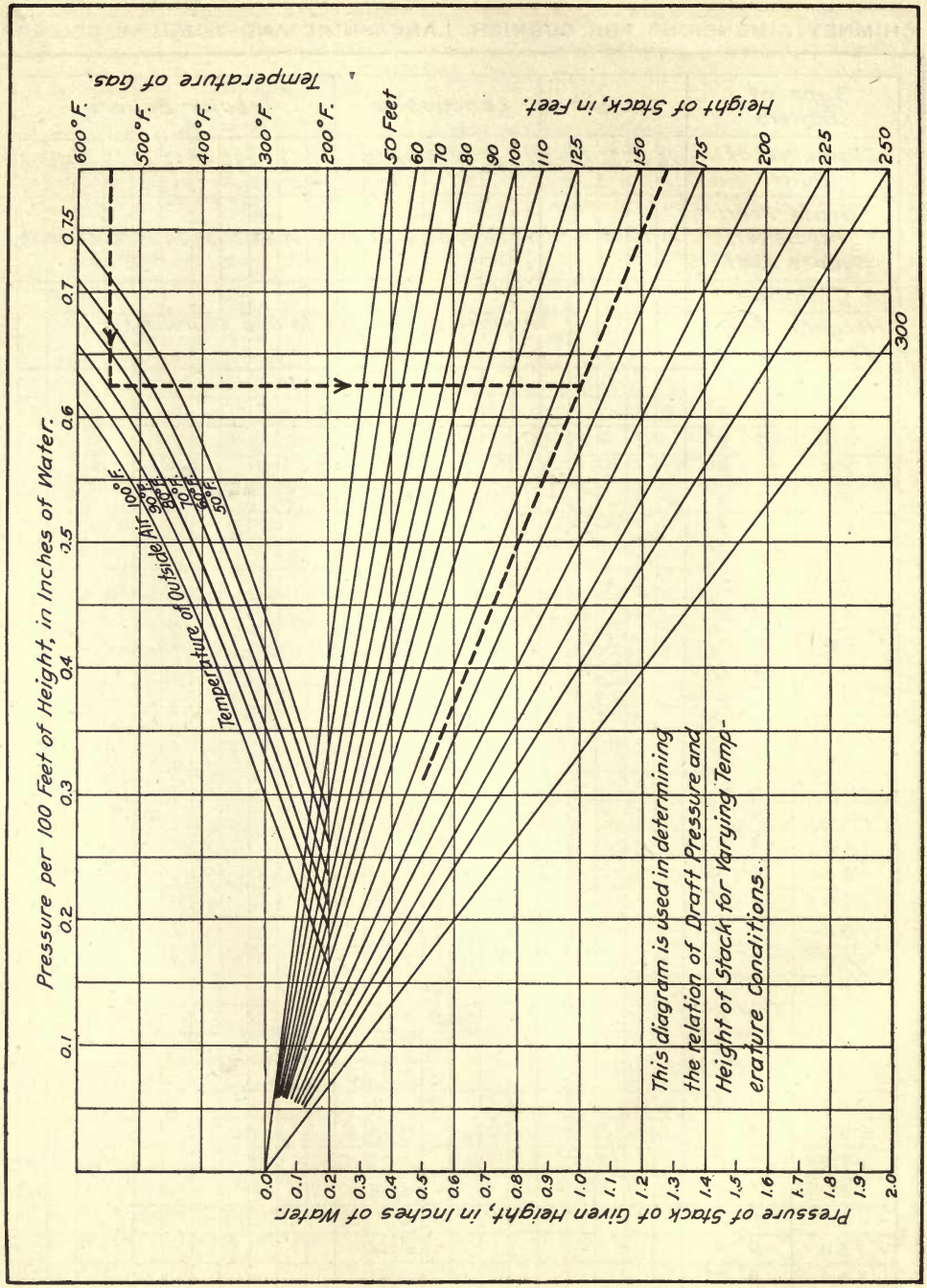
(Continued on page 32.)

CHIMNEY DIMENSIONS FOR CORNISH, LANCASHIRE AND TUBULAR BOILERS

Type of Boilers		Cornish					Lancashire							Tubular Boilers									
Diameter of Boiler		46"	50"	56"	60"	66"	60"	66"	70"	76"	80"	86"	90"	50"	56"	60"	66"	70"	76"	80"	86"	90"	96"	10'
Grate Area Per Boiler, Square Feet		10	14	15	16	21	22	26	30	36	39	44	47	10	14	16.5	21	30	34	38	39	43	46	49
Chimney		Number of Boilers to One Chimney																					
Height, Feet	Diam. Feet Inches																						
40	2' 0"	1	1	1										1	1	1							
45	2' 3"	2												2									
50	2' 6"		2		1		1								2		1						
55	2' 9"	3		2				1						3		2							
60	3' 0"	5	3			1			1	1				5	3			1	1				
65	3' 3"			3	2		2				1	1				3	2			1	1	1	
70	3' 6"		4					2					1		4							1	
75	3' 9"			4												4							1
80	4' 0"		5		3	2	3		2						5		3	2					
85	4' 3"			5				3		2						5			2				
90	4' 6"				4	3	4		3		2					6	4	3		2	2		
95	4' 9"				5		5	4				2					5					2	2	
100	5' 0"					4	6		4	3	3		2				6	4	3	3	3			2
105	5' 3"						7	5									7							
110	5' 6"					5	8	6	5	4		3					8	5	4			3		
115	5' 9"						9	7			4		3							4	4		3	
120	6' 0"						10	8	6	5		4						6	5			4		3
125	6' 3"							9	7		5		4					7		5	5		4	
130	6' 6"							10	8	6		5						8	6			5		4
135	6' 9"								9	7	6		5						7	6	6		5	
140	7' 0"								10		7	6							8	7	7	6		5
145	7' 3"									8			6										6	
150	7' 6"								12	9	8	7								8	8	7		6
155	7' 9"									10	9	8	7							9	9	8	7	
160	8' 0"										10		8							10	10	9	8	7
165	8' 3"									12		9												8
170	8' 6"										12	10	9									10	9	
175	8' 9"												10										10	9
180	9' 0"											12												10
185	9' 3"										15		12											
190	9' 6"											14												
195	9' 9"											15												
200	10' 0"												15											

Contributed by A. Wind, MACHINERY'S Data Sheet No. 126. Explanatory note: Page 26.

DRAFT PRESSURE AND HEIGHT OF STACKS FOR VARYING TEMPERATURES



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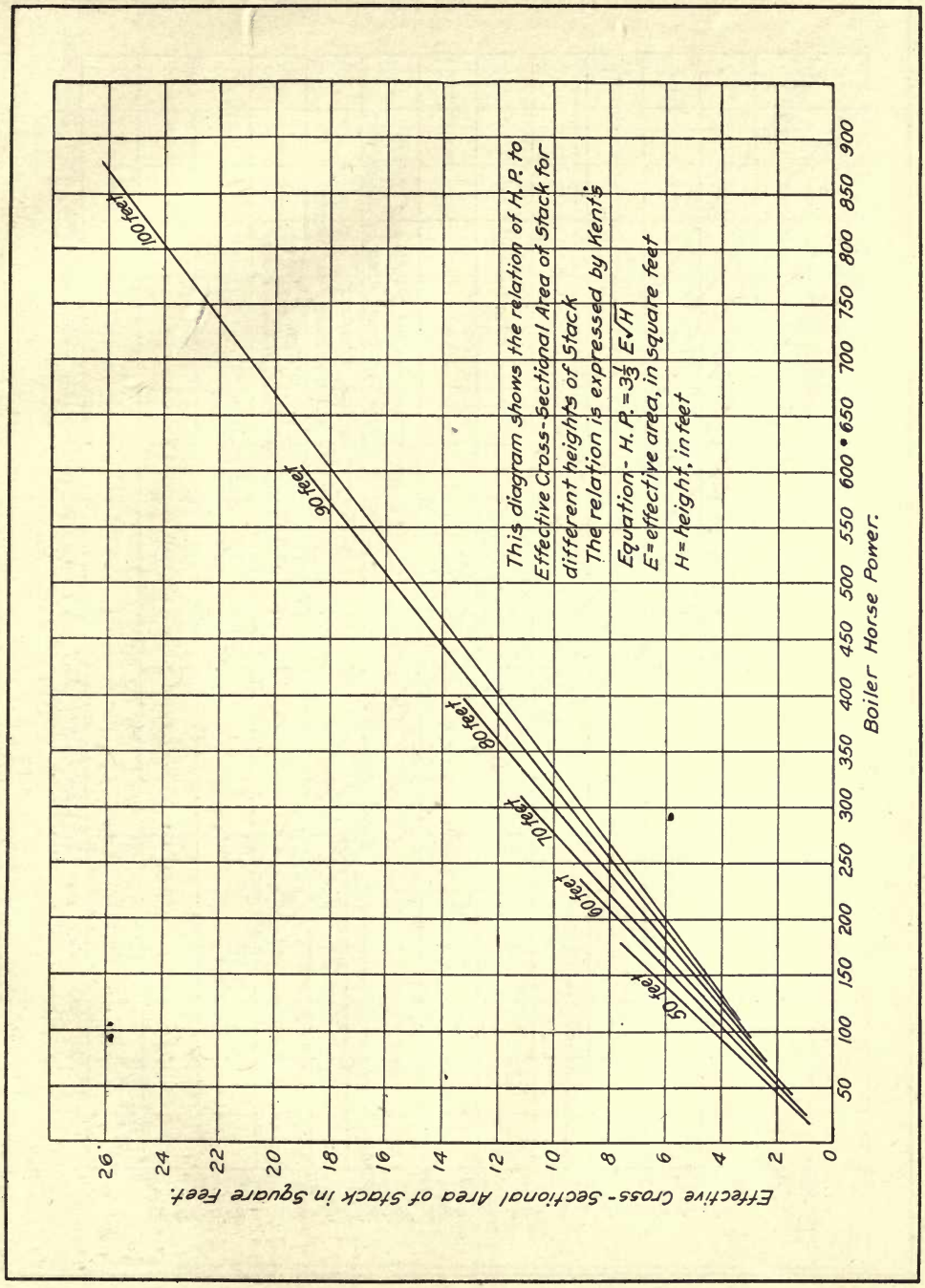
HORSEPOWER AND AREA OF STACKS—I



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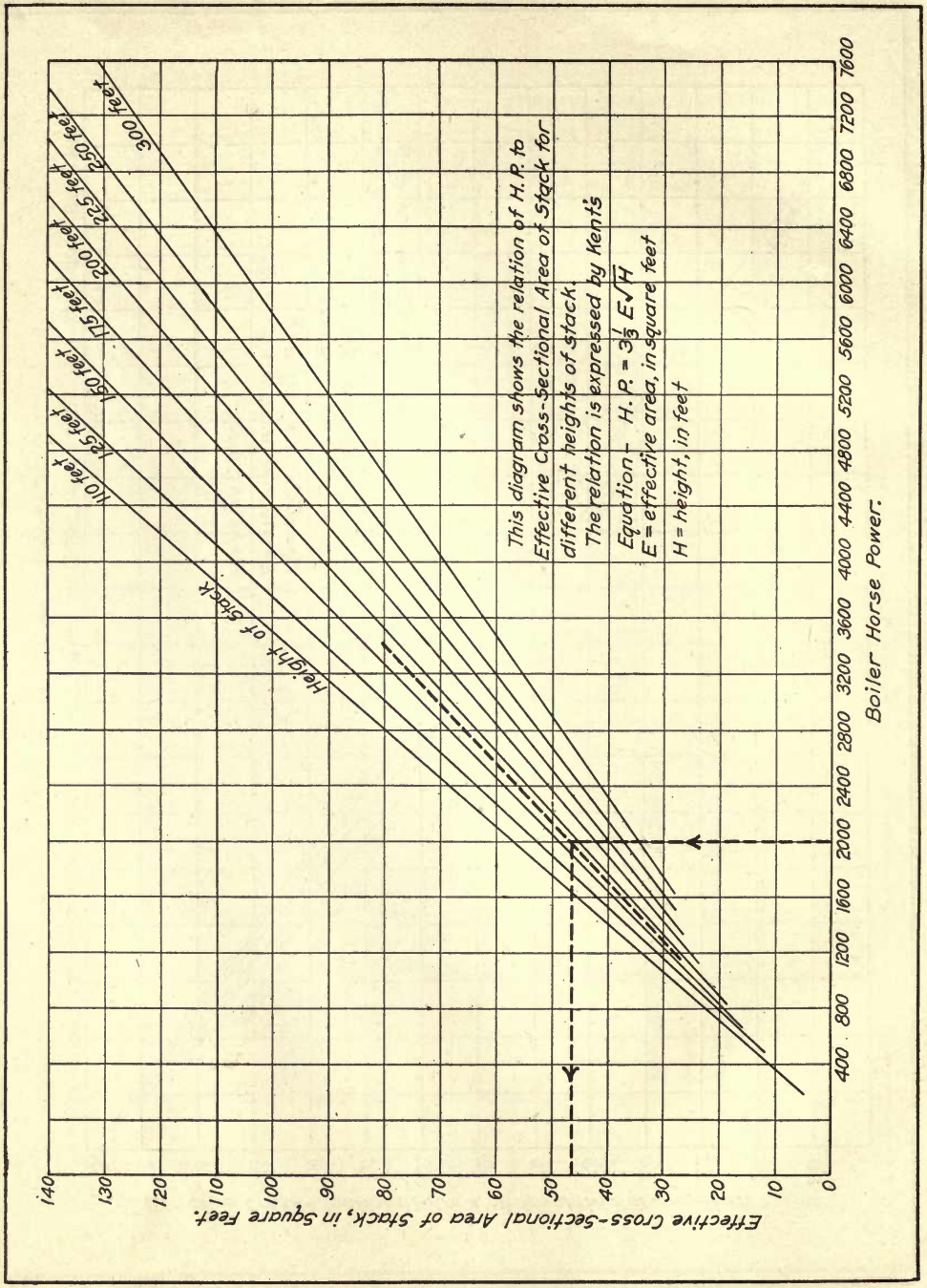
HORSEPOWER AND AREA OF STACKS—II



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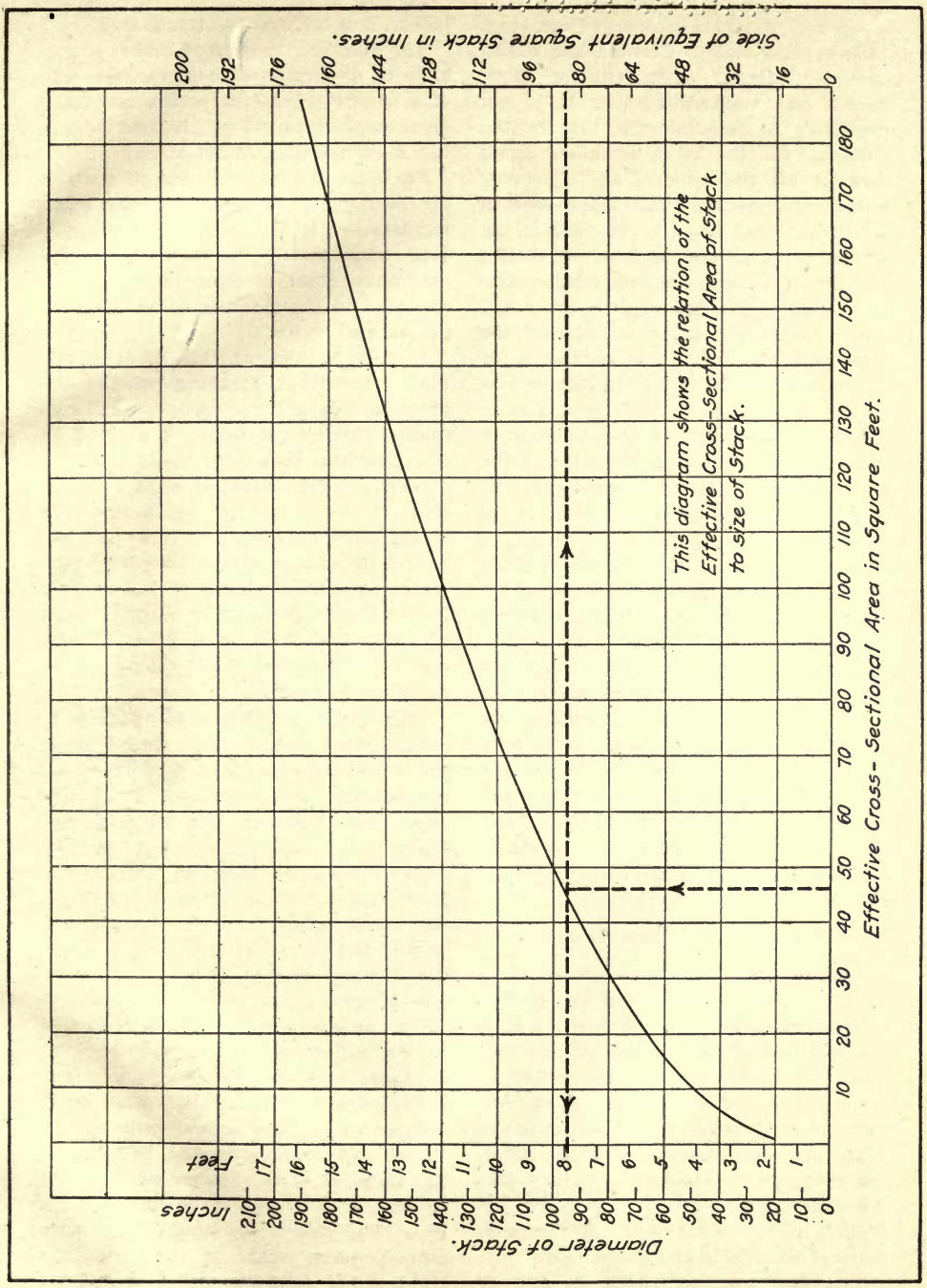
EFFECTIVE AREA AND SIZE OF STACKS



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er 25 feet long as in one 30 feet long. This applies also to Cornish and multitubular boilers. When two or more boilers are worked together it is not necessary to calculate the size of the chimney for the total combined grate area of all the boilers, as it is very seldom that all the boilers are fired in all furnaces at exactly the same time. Therefore, a greater number of boilers permits of a comparatively smaller size of chimney. The table gives the diameters of boilers, grate areas and the diameters and heights of chimneys for any number of boilers from one to five, in the case of the Cornish type, one to fifteen in the case of the Lancashire type, and one to ten in the case of the multi-tubular boilers. In each case the height of the chimney is taken to be 20 times its diameter.

Where forced draft or induced draft plants are installed, the size of chimneys can, of course, be considerably reduced. Each given size of chimney would prove sufficient for 33 per cent greater capacity than shown in the table, when such draft is employed. To determine the size of the chimney for six boilers with induced draft, for example, select the chimney corresponding to four boilers.

The sizes of chimneys in this table correspond to the ordinary practice in England. [MACHINERY, January, 1910, Boilers and Chimneys.]

Diagrams for Stack Design

The diagram on page 28 gives a double set of curves which are plotted for the relation between temperatures of flue gas and outside air, height of stack, and the draft pressure in inches of water. From this diagram we can determine the relation of the height to the draft pressure desired, with the different temperature changes. We can also determine the draft, if we know the height of the stack and the temperatures of the inside and outside air.

The diagrams on pages 29 and 30 show the relation between the height of stack, the amount of boiler horsepower, and the cross-sectional area.

The diagram on page 31 makes it possible to determine at a glance the side of a square stack having the necessary cross-sectional area, or the corresponding diameter of a round stack.

For example, we will design a stack for 2000 boiler horsepower; the stack temperature is 550 degrees F., and outside temperature 80 degrees F., the maximum summer temperature. The pressure on the stack is to be one inch pressure of water.

It may be well at this point to explain the exact meaning of the expression "boiler horsepower." The centennial standard horsepower adopted by the American Society of Mechanical Engineers in 1884 is defined as an evaporation of 30 pounds of water into dry steam under a pressure of 70 pounds per square inch above atmosphere from feed water at a temperature of 100 degrees F.; or the evaporation of 34-1/2 pounds of water from feed water at a temperature of 212 degrees F. into steam of the same temperature.

On page 28, starting at 550 degrees F. at the right of the sheet, run over to the curve representing 80 degrees F., temperature of outside air. From this point drop down to the horizontal line representing one inch pressure for the desired stack, in inches of water. The point found here gives us 160 feet for the stack height. Refer to page 30 to find the cross-sectional area. Where the vertical line at 2000 boiler horsepower crosses the line of the 160-foot stack, we get a point which, projected to the left of the sheet, gives a cross-sectional area of about 47 square feet. From page 31 we find the value of 47 square feet cross-sectional area on the curve, and running to the left we get the diameter of the stack corresponding to that area, which is 96 inches, or 8 feet. The side of the square stack with corresponding area, as shown to the right of the diagram, would be slightly less than 7 feet. [MACHINERY, August, 1909, Simple Method of Stack Design.]

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